This preferential action on the growing region suggests that 2,4-D owes its effectiveness to competitive action with the plant's native growth-regulating substances. The fact that 2,4-D itself has definite growth-regulating properties (*1*) further strengthens this assumption.

Although in practice 2,4-D is sprayed on the surface of weeds rather than on the soil, some of it is bound to come in contact with the soil. In order to determine spray residues in soils, a test was devised which was based upon the high sensitivity of radish seedlings to 2,4-D. When radish seed was germinated on cotton soaked in 2,4-D solutions, it was found that concentrations as low as 0.1 ppm cause a striking reduction in root and hypocotyl growth in comparison to seeds germinating in water. A similar effect was found in radish seedlings germinating in soils which had been sprayed with 2,4-D. Under the conditions of our experiments 2,4-D was detectable in soils up to three weeks after 0.15 per cent solutions were sprayed directly on the soil at a rate of 300 gallons per acre, and up to five weeks when 0.3 per cent solutions were applied.

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Control of Ragweed Pollen Production With 2,4-Dichlorophenoxyacetic Acid[1]

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In surveying the selective herbicidal action of 2,4-dichlorophenoxyacetic acid, Hamner and Tukey (*2*) found that ragweed was among the more sensitive of the common weeds. Since ragweed is probably the most important cause of pollen allergy, its control is of great importance both as an economic and a public health measure. It was desirable, therefore, to investigate further the application of 2,4-D to ragweed control and to point out the practical possibilities.

In many urban areas in the East and Middle West before the war considerable effort and expense was put into campaigns to eradicate ragweed by cutting or treatment with various herbicides. The success of this means of controlling allergy due to ragweed pollen, and public interest in it, could undoubtedly be greatly increased by the availability of a cheaper, more effective method. Grigsby (*1*) has recently reported the use of several of the newer herbicidal compounds in ragweed control and has suggested that 2,4-D may be more effective. The essential requirement of any method, as Grigsby points out, is to prevent the formation or shed of pollen; but it is also desirable (1) to cause as little damage to other vegetation as possible, (2) to leave no residue toxic to animals, and (3) to require the minimum in cost of materials, time, and equipment.

[1] Journal Paper No. 646 of the New York State Agricultural Experiment Station, Cornell University, 20 September 1945.

RESULTS

Beginning on 26 July, plots 5 yards square were treated at weekly intervals in three locations where both eastern species of ragweed, *Ambrosia artemisiifolia* L. and *A. trifida* L., were growing abundantly among other common weeds. The treatments were made by water sprays of 1,000 ppm of 2,4-D containing 0.5 per cent Carbowax 1,500, as described by Mitchell and Hamner (*4*), and were applied with a 5-gallon knapsack sprayer at the rate of about 100 to 200 gallons per acre. Notes on the stage of flower development at the time of treatment and frequent observations of the effects were made to determine the latest safe time for treatment to prevent pollen formation or shed.

At the time of the first series of treatments the majority of plants had racemes varying from a few millimeters to 20–30 mm. in length. Within 24 hours these plants showed pronounced epinasty and twisting of pedicels, leaves, and stem tips. By the fourth day the twisting was more severe, growing points were enlarged, longer racemes were pendant, and a few lower leaves were chlorotic. By the fourteenth day none of the involucres had opened, and no further development of the flowers had taken place. Many plants showed extensive swelling and splitting of stem tips and the death of lower leaves. By the twenty-eighth day (23 August) the tops of about half of the smaller plants were dead, and larger plants showed typical red and yellow fall colors and were dying back from the tips. Controls at this time had developed normally and were shedding pollen.

At the time of treating the second series of plots (2 August) some of the racemes were fully developed and involucres were starting to open. Symptoms developed similar to the first treatment, and by the twenty-first day (24 August) some plants were dead, and there was no sign of pollen shed. Most of the involucres had not opened, and in those which had, the pollen sacs were dead.

At the time of the third series (10 August) most of the involucres were open, and some of the pollen sacs were mature. Eighteen days later (28 August) the younger racemes and tips of the older ones were dead, and no pollen had been shed, but at the base of the older racemes there were empty pollen sacs and pollen could be squeezed from others. The fourth series (17 August), at the time pollen shed was starting, showed the same general symptoms by 28 August as the third treatment except that the proportion of surviving pollen sacs and the extent of shedding was greater. Though the third and fourth treatments clearly caused reduction in the amount of pollen shed, they were too late to prevent it completely. That the pollen shed from these late treatments was not altogether normal was indicated by their vacuolate condition, similar to the effect of 2,4-D on bindweed pollen (*6*). No test was made, however, of their allergenic properties.

These experiments indicated that the safest procedure would be to treat plants before the involucres are open. Limited trials with lower concentrations and more extensive experience with other weeds have indicated that concentrations lower than 1,000 ppm might be equally effective in stopping development of the flowering parts, though the response would probably be slower.

A preliminary trial was also made of a new method of treatment which shows great practical possibilities in the large-scale application of chemical agents to plants. On 6 August a test of 2,4-D with a fog machine[2] was made, in which a 1-per cent solution in SAE 30 oil was "fogged" across an area of mixed weeds at the rate of about 1 to 2 gallons per acre from the back of a truck moving 3 or 4 miles per hour. Despite unfavorable atmospheric conditions, cool and damp with updrafts, telemorphic effects were visible on ragweed up to 100 feet from the machine within 24 hours. A week later severe symptoms were found throughout the first 50 feet, and many plants were already dead in the first 10 feet. The response was at least as rapid and apparently as effective in preventing pollen shed as the water spray. Because of the possible advantage of more highly oil-soluble compounds in fog application, the ethyl ester of 2,4-D was prepared and tested on a small scale. Dimethyl ether aerosols gave responses on ragweed similar to 2,4-D.

Conclusion

Water sprays of 2,4-D at 1,000 ppm at sufficiently early stages of flower development were shown to be effective in preventing pollen shed, though further work may show that lower concentrations or rates of application would be sufficient. A preliminary trial with a fog machine showed excellent possibilities, and with further experiments to determine the best carrier, concentration, and technic of fog application it promises to be a more economical method than sprays. Apart from any differences in amounts of 2,4-D required in the two methods, the fog machine would have the advantages (1) of avoiding the large volumes of water necessary in spray methods, (2) of swifter application, and (3) of requiring considerably lower cost in equipment. This new technic of application, combined with relatively low cost, favorable selectivity of herbicidal action (*3*) and low toxicity (*5*), make 2,4-D a promising herbicide for ragweed control. It is hoped that these experiments will encourage others to test 2,4-D on a larger scale.

[2] Made available through the courtesy of the Todd Shipyards Corporation.

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Rapid Estimation of the Phytocidal Action of Chemicals[1]

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Recent reports on the herbicidal action of substituted phenoxy compounds (*1, 3, 5*)[2] have stimulated investigations of organic compounds which are essentially new to workers doing research on weed-control problems. The large number of organic compounds which might legitimately be selected for test as herbicides, together with the high cost and limited supplies of many of these chemicals, require that preliminary tests of their toxicity be simple, rapid, and economical. The utilization of *Lemna minor* L. (smaller duckweed) as a test plant fulfills most of these requirements.

The procedures here proposed should provide direct evidence of the effectiveness of chemicals for the destruction of aquatic plants—a matter of widespread interest and of economic importance. Tests with duckweed, however, will not necessarily indicate the magnitude of the toxic action of an unproved herbicide on a terrestrial plant. For investigators concerned with

[1] Work conducted for the purpose of improving methods for the chemical eradication of *Ribes* to control white-pine blister rust, *Cronartium ribicola* Fisher. Greenhouse and laboratory facilities, used by the Bureau of Entomology and Plant Quarantine at the University of California, Berkeley, are maintained in cooperation with the College of Agriculture through its Department of Forestry.

[2] The following features of 2,4-dichlorophenoxyacetic acid, a substituted phenoxy compound, differentiate it from compounds previously recognized as effective herbicides: (1) very low solubility in water, (2) telemorphic action, (3) effective killing action of small dosages, and (4) selectivity of toxic action. Data on the action of 2,4-dichlorophenoxyacetic acid as a differential herbicide are given by P. C. Marth and J. W. Mitchell (*Bot. Gaz.*, 1944, **106**, 224–232).